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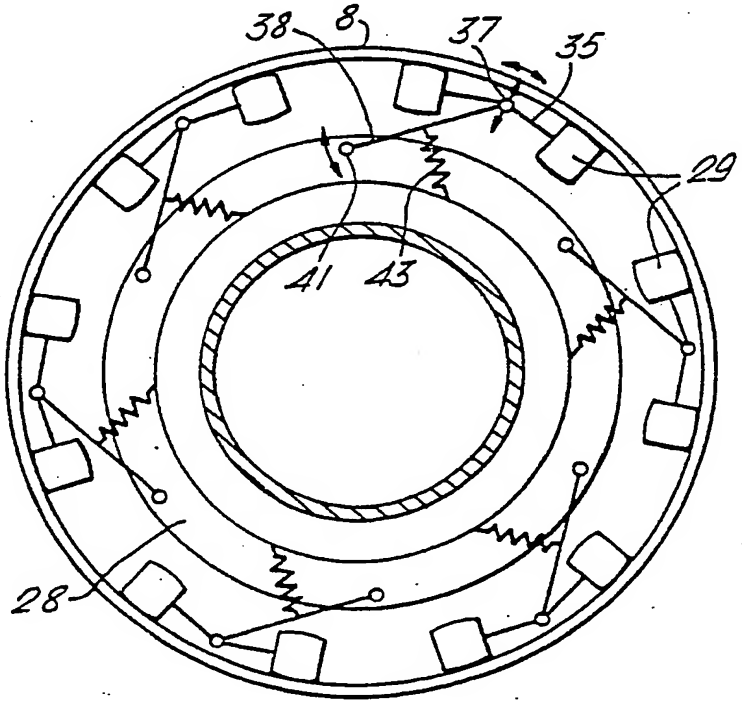
(57) Abstract

Pipe inspection device for ultrasonically inspecting the wall of a pipe. The device includes a support rocker arm (38) which is pivotally attached to an inspection vehicle (10) at one end, and at its other end pivotally supports a spindle (35) at the end of which two wheels (29) are rotatably mounted. One or more ultrasonic transducers (55) are disposed inside each wheel so that when the vehicle (10) is moved along the pipe, the wheels come into contact with the pipe such that the transducers (55) are aligned in predetermined positions relative to the pipe. The device may be arranged for insertion in the bore of the pipe, or for assembly around the outside of the pipe.



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Improvements in or relating to ultrasonic pipe inspection apparatus

This invention relates to ultrasonic pipe inspection apparatus. That is to say apparatus for insertion into the bores of pipes for the purpose of examining the wall of pipes for defects, cracks or other discontinuities. The invention is particularly concerned with wheel probes for ultrasonically inspecting the wall of the pipe.

The usual pipe inspection apparatus for examining, for example, gas pipe lines comprises a vehicle, or a train of vehicles, which is propelled along the pipe line by the gas flow in the pipe line. In one arrangement, ultrasonic transducers are mounted in a number of wheels (usually referred to as "wheel probes") which are urged into contact with the wall of the pipe. In use, ultrasound generated by the transducers is transmitted across the interface between the wheel probe and the wall of the pipe into the pipe wall. Ultrasound reflected or refracted from within the pipe wall is in turn received by the transducers within the wheels and subsequently analysed. This technique required intimate contact at all times between the wheels and the pipe wall so as to reduce or eliminate losses of the ultrasound signal at the interface between the wheel and the pipe wall.

One form of known wheel probe comprises a hollow wheel assembly having an inflatable tyre around its outer circumference, and the ultrasonic transducers located within the wheel assembly, and sound is transmitted through the inflatable tyre. In operation, the tyre is urged into contact with the surface to be examined, and an acoustic coupling fluid is maintained between the inflatable tyre and the surface to ensure that adequate coupling is achieved.

In some applications it is impossible, or impractical, to use a coupling fluid between the inflatable tyre and the surface to be examined. For example, in the case where it is desirable to examine many miles of pipe lines conveying natural gas.

If one accepts that there are instances when one cannot use a coupling fluid between the tyre and the surface to be examined, then the natural solution would be to force the inflated tyre into dry contact with the surface. However, this requires the tyre to be inflated to extremely high pressures to withstand the forces required to ensure adequate contact between the tyre and the surface.

In addition to the problem of inflating such tyres to high pressures in the case of examining many miles of gas pipe lines there are the problems of wear of the tyres, the possibility of punctures caused by encountering sharp obstructions at some weldments, and the material of the tyre must be chosen so as not to be deleteriously affected by the gas flowing in the pipe line.

An object of the present invention is to provide an improved wheel probe designed to remedy the aforesaid disadvantages and limitations of known wheel probes.

In co-pending British Patent Application based on British Patent Application 35352/77 there is described a wheel probe for insertion into the bore of a pipe for the purpose of ultrasonically inspecting the wall of the pipe. The wheel probe comprises a solid annular rim made of a non-deformable material through which sound will pass, and side members which together with the rim define a hollow chamber. One or more ultrasonic transducers are located within the chamber and are positioned adjacent the inside surface of the rim for directing and receiving sound through the rim, and a solid resilient tyre member mounted on the outside surface of the rim.

Co-pending British Patent Application dated 28th February, 1979, No. 79 07149 naming C.G. Braithwaite as inventor describes an inspection apparatus comprising a vehicle for movement along the bore of a pipe which will cater for bends in the pipe and, in some cases, will accommodate changes in the diameter of the pipe without upsetting, to an unacceptable degree, the alignment, positioning, and degree of contact between wheel probes in the bore of the pipe.

It is essential to locate the wheel probes accurately in the bore of the pipe at all times and in particular the wheel probes must be aligned so that the transducers are positioned at a predetermined angle to the tangent at the wall of the pipe in order to detect the echos or reflections or refractions of sound transmitted by that transducer or another transducer located in the same wheel probe or located in other wheel probes. Hence, it will be appreciated that it is usual to employ a plurality of wheel probes accurately positioned around the bore of the pipe and arranged to roll along the length of the pipe. This accurate positioning may be achieved using guide wheels as described and claimed in co-pending British Application 35354/77 (Agents reference 12000 LnX).

The present invention dispenses with the need for guide wheels, and acknowledges that it is usual to position a plurality of wheel probes around the circumference of the pipe. The present invention has as an object the provision of inspection devices which are self aligning relative to the pipe.

According to the present invention there is provided an inspection device for ultrasonically inspecting the wall of a pipe comprising a support means for attachment to a vehicle that in use is movable along the pipe, the support means carrying two spaced hollow wheels each having one or more ultrasonic transducers located therein, the two wheels being mounted for rotation on a common spindle means which is itself pivotally mounted on the support means so that the spindle means pivots about an axis which extends in a direction normal to the axis of rotation of the wheels at a location intermediate the wheels, the ulrasonic transducers being positioned relative to the wheels so that in use they are aligned in predetermined positions relative to the geometry of the pipe.

The inspection device may be designed for insertion in the bore of the pipe in which case, in use, the wheels are urged into contact with the bore of the pipe. Alternatively, the inspection device may be designed for assembly around the outside of the pipe in which case, in use, the wheels are urged into contact with the outside surface of the pipe wall.

The axes of rotation of the two wheels may lie on a common axis or parallel axes. Alternatively, the axes of rotation of the two wheels may lie in angular relationship to each other.

Preferably each wheel rotates on an axis which extends parallel to the tangent at the point of contact between the wheel and the pipe. That is to say that each wheel lies in a plane which extends radially of the pipe. Two or more transducers may be arranged inside each wheel with one transducer angled to direct, or receive, sound in one direction circumferentially through the wall of the pipe and another transducer angled to direct, or receive, sound in a second direction circumferentially through the pipe wall.

Preferably the support means comprises an arm assembly which in use is pivotally mounted on the vehicle, the spindle means being mounted on the free end of the arm assembly in such a way that, in use, the wheels can be urged into contact with the pipe wall. Preferably a biassing means, such as a coil spring, is provided to operate on the arm assembly to urge the wheels into contact with the pipe wall.

The arm assembly may comprise two spaced arms and the common spindle means is pivotally mounted on the free ends of the two arms.

Preferably guide means are provided for aligning the wheels in a preferred attitude relative to the pipe so that the wheels are aligned in the preferred attitude throughout the whole of the pivotal movement of the arm assembly.

In the case where the axes of rotation of the wheels are on a common axis or on parallel axes, the array of transducers may be arranged asymmetrically inside each wheel. In the case where each wheel rotates about an axis normal to a plane extending radially of the pipe the array of transducers may be arranged symmetrically inside each wheel.

An embodiment of the present invention will now be described, by way of an example, with reference to the accompanying drawings in which:

Figure 1 is a part sectional side elevation of an apparatus for ultrasonically inspecting the wall of a pipe incorporating a plurality of inspection devices constructed in accordance with the present invention;

Figure 2 is a fragmentary, partly broken away end view of the apparatus of Figure 1 looking in the direction of arrow A;

Figure 3 is a sectional side elevation of one of the wheels of one of the inspection devices incorporated in the aparatus of Figure 1;

Figure 4 is a sectional end view of the wheel of Figure 3 sectioned along line YY of Figure 3, and

Figure 5 is a line diagram of part of the apparatus of Figure 2.

Referring to Figure 1 the apparatus is intended for insertion in a 24-inch diameter gas pipe line (not shown) and comprises a vehicle 10 provided with a towing eye 9 which enables the vehicle 10 to be towed by a second vehicle (not shown) which is propelled along the pipe line by the flow of pressurised gas in the pipe. The vehicle is the subject of our aforesaid co-pending British Patent Application No. 79 07149 dated 28th February, 1979..

The vehicle 10 comprises a central hollow tubular member 11 having two flanges 12, 13, each of which is located at or near respective ends of the vehicle. Alignment means 14 are mounted on each flange for the

purpose of locating and aligning the vehicle 10 along the axis of the pipe. Each alignment means 14 comprises an annular sealing member 15 made of an elastomeric material such as polyurethane and has a concave recess facing towards the rear of the vehicle 10 so that pressurised gas in the pipe urges the sealing member 15 into engagement with the bore of the pipe. The annular sealing member 15 is clamped between an annular plate 16 and a clamping plate 17, and the annular plates 16 are secured by bolts 18 to the respective flanges 12, 13.

Four brackets 19 equi-spaced around a common pitch circle are secured to the front annular plate 16, and a link 20 is mounted by a spherical ball joint 20a at one end to a pivot 23 in each bracket 19 to provide the constraining means. A spherical ball joint 20a in the free end of each of the links 20 locates about a pivot 23 in a respective bracket 19 secured to an annular support plate 70, the brackets 19 being arranged so that the pivots 23 lie approximately radially relative to the front annular plate 16.

The support plate 70 forms part of a carrier 21 having two annular carrier plates 28 spaced apart in parallel relationship by hollow spacers 71 and secured together by bolts 74 extending through the spacers 71, the bolted-together carrier plates 28 being fixed to the suport plate 70 by bolts 27. The carrier 21 is freely movable in a plane normal to the longitudinal axis of the vehicle 10, and is suspended on a spring 24 attached to the annular plate 17 of the rearmost alignment means 14 and the rearmost carrier plate 28. The carrier 21 has a rubber centralising member 26 clamped between a clamping plate 25 and the support plate 70 to centralise the carrier 21 in the bore of the pipe. Eight inspection devices 22 are resiliently supported between the carrier plates 28 as shown in greater detail in Figure 2 to which reference is also made.

Each inspection device 22 comprises two hollow wheels 29, each wheel 29 having inside thereof an ultrasonic probe assembly 30 with transducers 55 arranged to transmit sound into the wall of the pipe so that the sound travels around a circumferential band of the pipe wall. Power for energising the transducers 55, together with the signals

representative of the sound received from within the pipe are fed by way of leads (not shown) either to the towing vehicle or to a further vehicle (not shown) which is towed behind the vehicle 10. Each wheel 29 is shown in greater detail in Figures 3 and 4 and comprises an hermetically sealed hollow body 31 made of polymethylmethacrylate (Perspex - a Registered Trade Mark) rim 32 and brass side-plates 33 secured to the rim 32. The rim 32 is provided with a solid polyurethane tyre 34 around its circumference. The wheels 29 are mounted on bearings for rotation on a spindle 35 carried by taper block 36. "O" ring seals are provided between side plates 33 and the rim 32 and oil seals are provided between the side-plates 33 and spindle 35.

The block 36 is itself pivotally mounted on a spindle 37 carried at the free end of the limbs of a generally "U"-shaped pivot arm 38. The wheels 29 are thereby able to pivot about the axis of the spindle 37 so that the two wheels of each inspection device 22 contact the bore of the pipe along lines which are equispaced each side of a radial plane passing through the longitudinal axis of the pipe and the longitudinal axis of spindle 37. The spindles 35 lie normal to radial planes passing through the point of contact between the wheel and the bore of the pipe.

The ultrasonic probe assembly 30 is resiliently carried by the spindle 35 and the hollow wheel contains an acoustic coupling medium (not shown) such as for example a mixture of glycerol and water. In some instances the glycerol and water mixture may be loaded with particles of carbon, for example graphite, or molybdenum disulphide.

The ultrasonic probe assembly 30 includes a support structure, consisting of brackets 52 and rods 53 which are arranged to support a nylon block 54 upon which are mounted a plurality of transducers 55, for transmitting ultrasound into the wall of the pipe and for receiving sound scattered or reflected from the wall of the pipe. The block 54 is urged against the inside surface of the rim 32 by a tension spring 56 which is anchored between one of the brackets 52 and a pin 57 secured in a central block 58 which forms part of the spindle 35. The rods 53 are slidably supported in the spindle block 58 for linear movement of the probe

assembly. The block 54 is shaped to conform with the shape of the inside surface of the rim 32, so as to ensure that the beams of sound from the transducers 55 enter the pipe wall at a predetemined preferred angle, and that the acoustic coupling medium is permitted to penetrate any gaps between the transducers 55 and the block 54 and between the block 54 and the rim 32. Electrical leads (not shown) from the transducers 55 pass along a bore (not shown) in the spindle 35 through seals which prevent the acoustic coupling medium leaking from the wheel 29 and out through the tapered block 36.

The pivot arm 38 comprises two spaced side members 39, 40 connected by a shaft 41 about which the pivot arm 38 rotates. The pivot arm 38 is mounted between the carrier plates 28, and a spring assembly 42 operates on each side member 39, 40 to urge the wheels 29 radially outwards into engagement with the bore of the pipe. Each spring assembly 42 comprises a compression coil spring 43 mounted on a rod 44 which is rigidly mounted at one end on the carrier plate 28. The coil spring 43 passes through an elongate slot 45 in the pivot arm 38, and urges a thrust pad 46 into engagement with a concave surface of a bracket 47 secured to the pivot arm 38.

Each tapered block 36 is provided with spigots 48 which engage in guideways 49 provided in end stops 50, 51 carried by the carrier plates 28. The guideways 49 are shaped to provide a limit to the pivotal movement of tapered block 36 while allowing some pivotal movement of tapered block 36 when wheels 29 are negotiating irregularities in the pipe surface such as ovality or welds. The guide may also assist in maintaining the wheels 29 correctly aligned relative to the pipe wall so that the wheels 29 contact the pipe wall along lines equispaced about radial planes.

The movement of the wheels 29 relative to the vehicle may be seen in line diagramatic form in Figure 5 to which reference can be made, and in which the wheels 29 are shown in engagement with a pipe 8. As an alternative to the use of pivot support arms, the support arms may be linearly displaceable, for example in radially directed grooves.

It is to be understood that the specific design of transducers and their positions inside the wheels may be different from that described above. For example, instead of mounting the ultrasonic probe assembly into contact with rim 32, the block 54 may be dispensed with and the transducers of ultrasonic probe assembly fixed rigidly to spindle 35 and held a small distance away from the rim 32 of the wheel. In this case the wheel is filled with a mixture of glycerol and water loaded with particles of carbon, for example graphite, or molybdenum disulphide. The size of the particles is chosen so as to attenuate slightly the ultrasound, thereby reducing ultrasound reverberation within the wheel after the transmission of an ultrasonic pulse from a transducer.

Claims

1. An inspection device for ultrasonically inspecting the wall of a pipe, the device comprising a support means for attachment to a vehicle that in use is movable along the pipe, the support means carrying two spaced hollow wheels each having one or more ultrasonic transducers located therein, the two wheels being mounted for rotation on a common spindle means which is itself pivotally mounted on the support means so that the spindle means pivots about an axis which extends in a direction normal to the axis of rotation of the wheels at a location intermediate the wheels, the ultrasonic transducers being positioned relative to the wheels so that in use they are aligned in predetermined positions relative to the geometry of the pipe.

2. A device as claimed in Claim 1, wherein the device is adapted to urge the wheels into contact with the bore of the pipe.

3. A device as claimed in Claim 1, wherein the device is adapted to urge the wheels into contact with the outside surface of the pipe.

4. A device as claimed in any one of the preceding Claims, wherein the axes of rotation of the two wheels lie on a common axis.

5. A device as claimed in any one of Claims 1 to 3, wherein the axes of rotation of the two wheels lie on parallel axes.

6. A device as claimed in any one of Claims 1 to 3, wherein the axes of rotation of the two wheels lie in angular relationship to each other.

7. A device as claimed in any one of the preceding Claims, wherein each wheel is rotatable on an axis which extends parallel to the tangent at the point of contact between the wheel and the pipe.

8. A device as claimed in any one of the preceding Claims, wherein two or more transducers are arranged inside each wheel with one transducer

angled to direct or receive sound in one direction circumferentially through the wall of the pipe, and another transducer angled to direct or receive sound in a second direction circumferentially through the wall of the pipe.

9. A device as claimed in any one of the preceding Claims, wherein the support means comprises an arm assembly which in use is pivotally mounted on the vehicle so as to pivot in a radial plane and thereby cause radial displacement of the spindle means relative to the vehicle.

10. A device as claimed in Claim 9, wherein biasing means are provided for urging the arm assembly radially outwards to cause the wheels to contact the pipe wall.

11. A device as claimed in any one of the preceding Claims, wherein guide means are provided for aligning the wheels in a preferred attitude relative to the pipe.

12. A device as claimed in Claim 4 or Claim 5, wherein the transducers are arranged asymmetrically inside each wheel.

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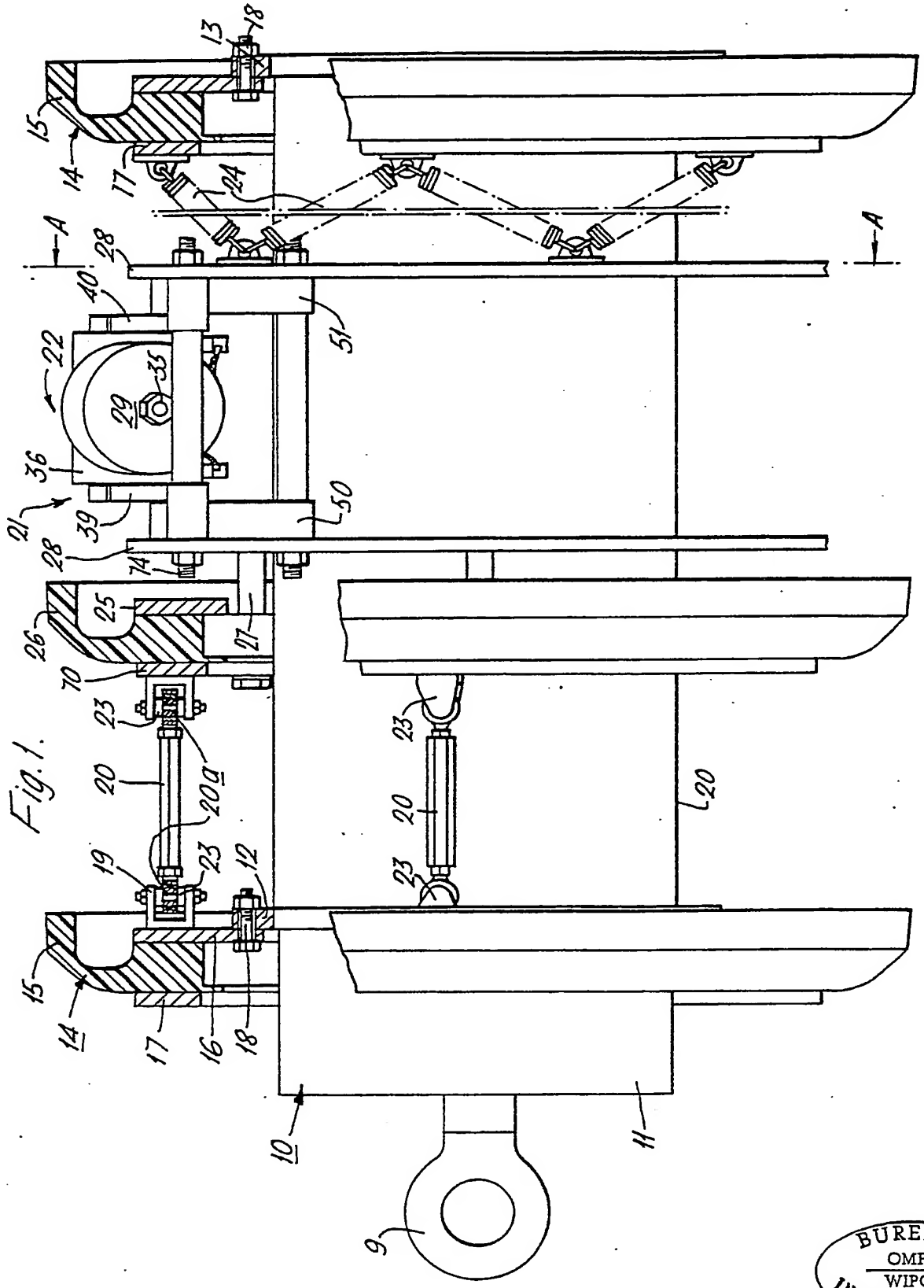

Fig. 1.

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Fig 2.

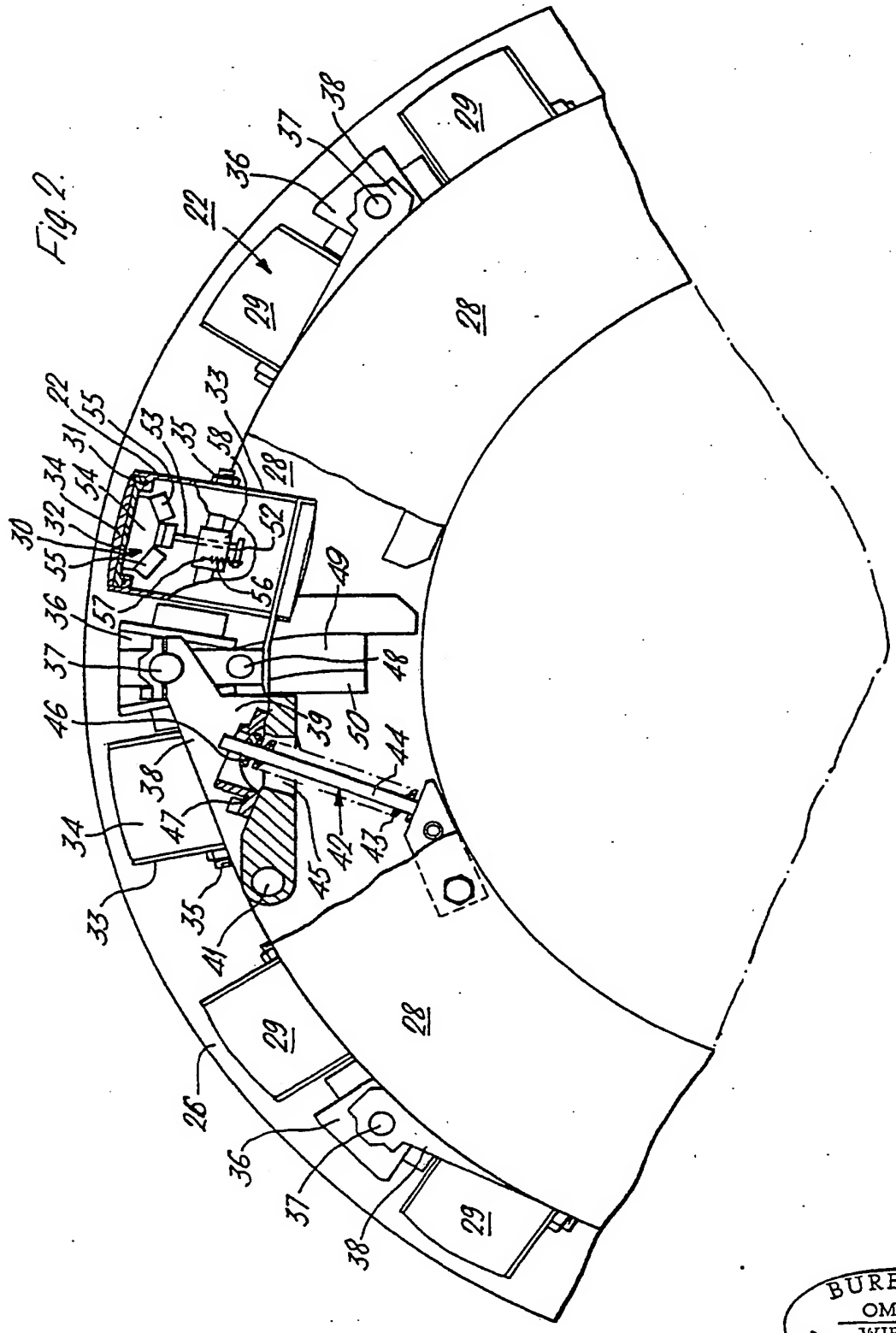

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Fig. 3.

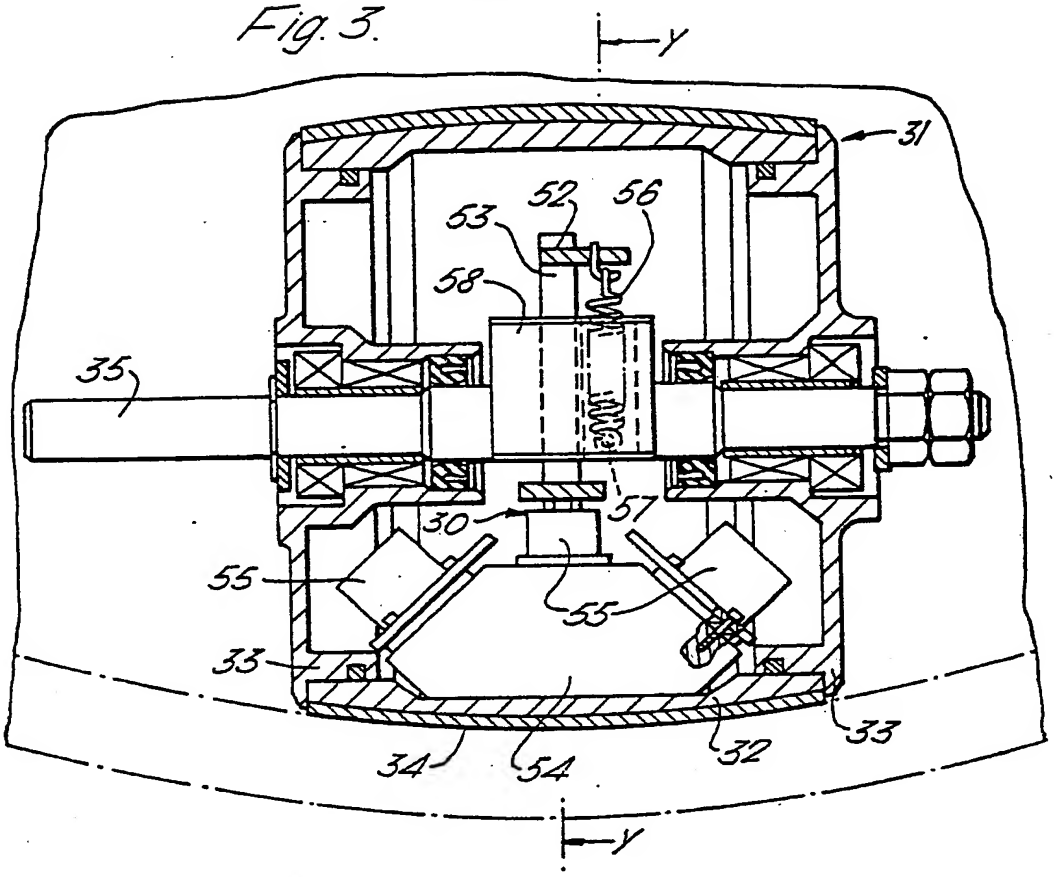

Fig. 4.

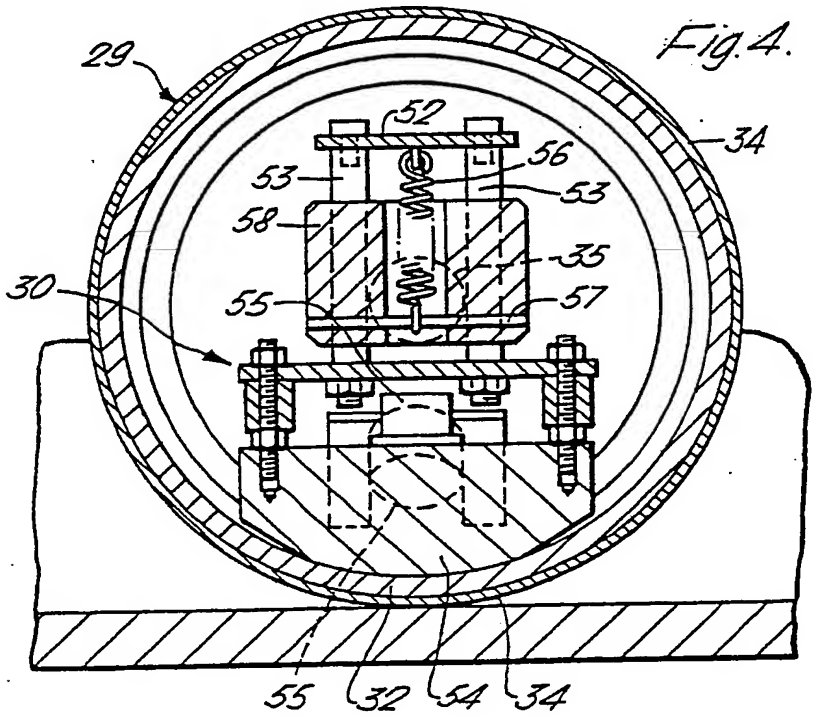

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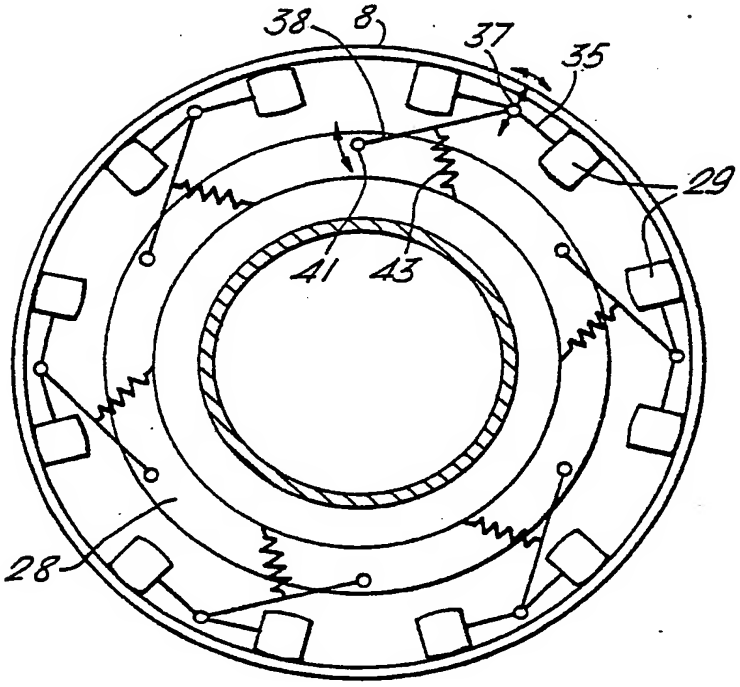
Fig. 5.



INTERNATIONAL SEARCH REPORT

International Application No FCT/GB 80/00029

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[3]: G 01 N 29/04; G 01 N 37/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
Int.Cl.[3]	G 01 N 29/00; G 01 N 37/00; F 17 D 3/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 3628375, published December 21, 1970, see the whole document, D.A. Pagano	1
A	DE A, 2021278, published November 11, 1971, see the whole document, Stahlwerke Peine-Salzgitter A.G.	1
A	US, A, 3029382, published April 10, 1962, see the whole document, K.W. Cochran	1
A	US, A, 3299350, published January 17, 1967, see the whole document, D.R. Tompkins	1

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"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
April 17, 1980	April 25, 1980
International Searching Authority [1]	**Signature of Authorized Officer [20]**
European Patent Office	G.L.M. KRUYDENBERG

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